Chapter 8
Risk Management

8.1 Cost-Effectiveness

To make prudent resource management decisions, one must consider the cost of each resilience tactic as well as its effectiveness. One tactic might be capable of reducing more than twice the BI losses of another, but if it costs ten times as much to implement, the former is not the better option.

We begin with a general overview of cost considerations. Most adaptive conservation more than pays for itself when it represents a productivity improvement, such as an increase in energy-efficiency (producing the same amount but with less energy). A more general definition of conservation (reducing the amount of an input irrespective of its effect on output) can incur net positive costs.[1] Input substitution requires a small penalty for using a less optimal input combination. Import substitution involves an increase in costs from utilizing higher-cost sources and/or increasing transportation distances. Relocation can be somewhat expensive if it involves a physical move; however, the increasing role of telecommunications, and the prospects for working in cyberspace and tele-commuting, have significantly decreased this cost. Emergency planning exercises take little time and incur relatively low costs. Production rescheduling involves the payment of overtime wages.

Some resilience tactics are primarily inherent, and simply await their utilization once the disaster strikes. The cost of inventories is just the carrying charge and not the value of the inventories themselves, which simply replace resources that would've been paid for otherwise. Excess capacity involves a similar cost, though some of this capacity is often planned in order to enhance business flexibility or to accommodate downtime for maintenance; these aspects should not be charged to disaster resilience. Production Isolation, instances where some production activities are separated from the need for one or more inputs, is inherent in the system, and

[1] Conservation often involves the installation of energy-saving equipment. When this more than pays for itself, an energy-efficiency improvement has taken place.

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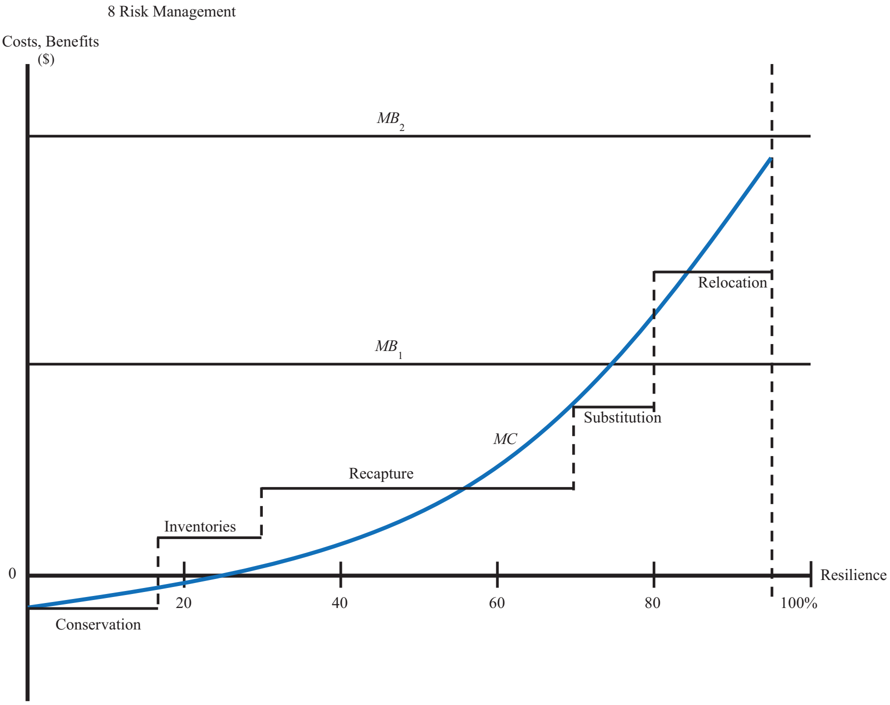

Fig. 8.1 Benefit-Cost Analysis of Resilience

should likewise not be charged to resilience unless it is expressly done for that purpose.

Once the cost per unit of effectiveness, expressed in percentage terms or in terms of dollars of net revenue from business interruption loss prevention, is determined the options should be ranked from lowest cost to highest, as depicted in the stylized example in Fig. 8.1. The result is the increasing marginal cost curves (a step-function thus far); this limit would be the maximum percentage or dollar amount of resilience possible. Note that since most conservation more than pays for itself, the function begins in the negative cost range.

The cost of each resilience tactic is affected by the context in which it is implemented. First, for any given tactic, its cost is not likely to be constant over the range of application (effectiveness). Nearly all economic processes eventually exhibit diminishing returns, resulting in a marginal cost curve (or step-function for now) that increases at an increasing rate, as in Fig. 8.1. For example, there might be several conservation options, likely with different costs. Import substitution would be another example, where increasing amounts would need to be brought in from longer distances, or even higher cost suppliers at the same distance. Diminishing returns are also likely applicable in the cases of relocation and technological change. This consideration provides a rationale for fitting a curve through the step function as is done in Fig. 8.1. Note also that the total cost of achieving any target level of resilience is reflected by the area under the marginal cost (MC) curve; it represents the mathematical integration of the first-derivative (marginal term) to yield the total.

The context in which the disaster strikes and resilience is implemented also has an influence on the effectiveness side. Relevant factors include the disaster type, magnitude, and recovery duration, as well as background conditions relating to the economy, such as its economic health at the time of the disaster and its geographic location. For example, inventories are finite and more likely to run out in disasters for which the duration of recovery is long. Production recapture also erodes over time, as customers begin to seek other suppliers. Excess capacity is dependent on the business cycle (e.g., one reason that relocation was so effective after the World Trade Center attacks was because New York City was in the throes of a recession, which then provided a great deal of vacant office and manufacturing space).

8.2 Benefit-Cost Analysis

Resilience can be couched in a benefit-cost analysis (BCA) framework by bringing its rewards formally into the picture. For purposes of simplification, we can think of the benefits as the net revenue of business interruption losses avoided. At first this might best be represented by a horizontal marginal benefit (MB) curve, reflecting equal additional increments of benefits for each percentage increase in resilience. For example, if potential BI losses are $1,000,000 in net revenue terms, then each percentage of resilience has a marginal benefit of $10,000. In this case, the marginal benefit function is constant by definition.[2] If the horizontal axis of Fig. 8.1 were measured in terms of physical units of production, then it could be non-linear. The optimal level of resilience would be at the point at which the marginal cost and marginal benefit curve intersect.[3] Even without a precise numerical example, we can draw some insights from Fig. 8.1. All cost-saving resilience options would be taken, because they yield guaranteed net benefits. Also, given the relatively low cost of many of the tactics, at least in some of their initial applications, it is likely that a fairly high level of resilience would be chosen.

[2] For example, economies of scale would actually increase the marginal benefits successively as resilience is carried out, counter to the more standard downward-sloping marginal benefit curve. Net revenue would also increase if fixed costs are significant. Working in the opposite direction, however, would be factors such as keeping the business open at some minimum level for the sake of its public image. The most significant factor affecting the MB curve, however, would be on the gross revenue side. The perfectly competitive firm could sell as much of its product as needed at a constant price to maximize profits, which is essentially at a constant marginal revenue. However, firms in imperfectly competitive markets would face a declining marginal revenue curve, putting pressure on the net revenue function to decline as well.

[3] This condition holds even for an increasing marginal benefit curve, as long as its slope is flatter than the marginal cost curve.

We note additional considerations relating to important characteristics of resilience tactics. One pertains to whether a given tactic yields benefits only to an individual business or whether these benefits apply more broadly. Nearly all of the micro-level resilience tactics that we have discussed thus far, with a focus on the customer-side, have limited spillover effects. However, the opposite is true for resilience tactics on the supplier-side. An example is that of redundancy, such as the presence of a back-up water pipeline system. In this case, the benefits are not simply limited to maintaining revenue to the supplier, but to avoid business interruption for all its customers. Thus, while redundant systems are relatively much more expensive than the resilience options just discussed, their benefits are much more widespread. In fact, they basically exhibit something akin to "public goods" benefits.

A further consideration needs to be taken into account on the cost side for redundant systems, as well as some demand-side tactics, such as inventories or back-up equipment. Rose (2009) and others make the case that customer-side resilience tactics need not be implemented until the disaster strikes, which would appear to give them a cost advantage over mitigation and supplier-side tactics such as redundancy. However, most forms of inherent resilience, such as inventories and back-up, are in place whether or not the disaster strikes. While they lack the flexibility that other customer-side tactics have, there is a positive ramification of this—they exist to protect against *many* threats over the course of their lifetime. Thus, their cost-effectiveness is much higher than if one considers only a single threat. The MB function in our analysis can readily be adjusted for these features by incorporating all of these benefits of implementing the given resilience tactic and also considering a distribution of threats for which it reduces BI losses. Thus, the larger the number of customers the water utility with a redundant system serves, the greater its benefits, and the more threats a stockpile protects against, the greater its benefits.

We illustrate these points in relation to a tactic such as redundancy in Fig. 8.1. The MB curve we have been discussing thus far ($MB_{1)}$ would be raised significantly if we took into account that it protects against a distribution of threats (see, e.g., $MB_{2)}$. On the other hand, we would have to multiply the benefits by the probability of their occurrence, which would put downward pressure on the MB curve. In the vast majority of cases, the net effect would be a lower MB curve because the probabilities of extreme events are so low.

Also, the fact that benefits of a redundant system accrue beyond simply the electric or water utility providing the service and extend to all of their customers would significantly increase the overall benefits. Implicitly, the MB curve has been defined thus far in terms of the rewards to the entity implementing this resilience tactic—the electric or water utility. However, the gains to all the customers are likely to be much greater; in essence, these gains would be the net revenue losses prevented by this resilience tactic, and thus likely to be at least an order of magnitude larger than the benefits to the utility itself.[4] The latter essentially represents a type of social benefit of implementing the resilience tactic. This is what is illustrated by MB_2 in Fig. 8.1, which is significantly higher than MB_1, though not necessarily drawn to scale.[5] One further ramification of this situation is the difference between the private optimum and social optimum, as well as the associated motivations. The utility's decision to implement this resilience tactic would be based on its own private marginal benefits, while, from the standpoint of society, it would be best to implement a higher level (the classic "public goods" optimal resource allocation problem). This raises public policy issues related to how to induce behavior consistent with the best interests of society as a whole. The desired outcome is likely to be achieved more readily in the cases of government-owned or -run utilities. For investor-owned utilities, subsidies or some form of regulation would be required.

The reader is referred to Rose (2016) for empirical estimates of benefit-cost ratios for resilience tactics in the electric utility example presented in the previous chapter. The analysis discusses several of the complications that must be addressed in the estimation process.

References

Rose A (2009) Economic resilience to disasters. Community and Resilience Institute Research Report Number 8. ORNL

Rose A (2016) Benefit-cost analysis of economic resilience actions. In: Cutter C, S (ed) Oxford research encyclopedia of natural hazard science. Oxford University Press, New York, forthcoming

[4] The order-of-magnitude estimate stems from a simple back-of-the-envelope calculation. Electricity and water inputs represent less than 5 % each on average of total production costs of nearly all businesses in the economy. Assuming, rates of return (or profit rates in general) are reasonably equal across all business enterprises, again on average, this means that net revenue losses are more than 20 times higher for the economy than for the utility supplier. Moreover, this number increases when indirect (multiplier or general equilibrium) effects are taken into account.

[5] Strictly speaking only resilience tactics that have this characteristic (mainly supply-side ones) would have their MB segments raised. This would make for a likely non-monotonically increasing or decreasing MB curve and would complicate the identification of an optimum.